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The Fauna of Ground Beetles (Coleoptera: Carabidae) in Paddy Fields, Four Province, Korea

Jinyoung Park[1], Seong Joon Park[2] and Jong Kyun Park[1]*
[1]*Department of Applied Biology, College of Ecology & Environmental Sciences, Kyungpook National University, Sangju 742-711, Republic of Korea*
[2]*National Institute of Environmental Research, Incheon-si, 404-708, Republic of Korea*

Abstract: A total of 29 species belonging to 17 genera of 10 subfamilies were identified from 277 collected ground beetles in paddy fields. [Species richness was high in Harpalinae (9 species, 31.0%), Pterostichinae (8 species, 27.6%), Callistinae (4 species, 13.8%), Nebriinae (2 species, 6.9%), and others subfamilies (1 species, 3.4%). The subfamily Harpalinae had the most number of individuals (24.5%), followed by 63 Callistinae (22.7%), 59 Zabrinae (21.3%), and 48 Brachininae (17.3%), 19 Pterostichinae (6.9%), 8 Licininae (2.9%), Nebriinae (2.5%), 3 Patrobinae (1.1%), and 1 other subfamily (0.4%), respectively. The dominant species was *Amara congrua* (59 individuals, 21.3%) and the subdominant species was *Chlaenius pallipes* (49 individuals, 17.7%)]. Between Site 4 (Chuncheon-city, Gangwon-do) and Site 5 (Gangneung-city, Chuncheon-city, Gangwon-do) and between Site 1 (Yuseong-gu, Daejeon metropolitan-city) and Site 2 (Danyang-gun, Chungcheongbuk-do) had the highest similarity in the result of cluster analysis using the surveyed ground beetles.

Keywords: Carabidae, Monitoring, Inventory, Diversity, Paddy Fields, Field

Introduction

A paddy field is a flooded parcel of arable land used for growing rice and other semi-aquatic crops. Paddy fields account for approximately 15% of the global arable land area (Huke and Huke, 1997, Maclean *et al*. 2002). In South Korea, paddy fields are the most common type of agricultural land, covering approximately 60% of all agricultural land (Do *et al*., 2011).

Paddy fields provide forage, refuge, and a place for overwintering or estivation for many species, including soil macrofauna and microfauna, insects, and birds (Kato, 2001, Thomas *et al*., 2004, Katoh *et al*., 2009, Paik *et al*., 2009). Among these, ground beetles except Halpalinae and Zabrinae, are predaceous and a natural enemy of small-sized invertebrates including earthworms, aphids, moths and snails, that play a very important role in the ecosystem (Lövei and Sunderland, 1996; Holland, 2002) and this considers ground beetles an important natural enemy group in mountainous areas and agricultural environment (Kromp, 1999; Holland, 2002). More specifically, in wet habitats such as paddy fields, abandoned paddy fields, wet grasslands, riversides, and lowlands with different vegetation, lower soil pH, and higher soil moisture than surrounding areas, ground beetles can be characterized by species composition, food preference, and habitat selection (Hengeveld, 1987, Luff *et al*., 1989, Eyre *et al*., 1990, Do and Moon, 2002, Do *et al*., 2007). Some of these studies have examined the effectiveness of restoring abandoned paddy fields with respect to improved agricultural landscape biodiversity (Comín *et al*., 2001, Yamada *et al*., 2007, Uematsu *et al*., 2010).

The study was performed to make specific inventories of ground beetles in paddy fields and to provide fundamental information and diversity on community structure of ground beetles.

Materials and Methods

Survey Sites and Collecting Method

Ground beetles mainly live on the surface of the paddy fields and pitfall traps are installed considering these features. There are 10 traps at 10 m interval for each and the top of the trap is placed at the same height of the surface of the paddy field. Transparent plastic bottles with 10.0 cm height, 7 cm diameter and 200 mL volume were used as traps and had plastic filters with 6 holes at 2 cm diameter to prevent from mid- and large-sized animals like rodents. Traps were filled with preservatives (50 mL, environmentally friendly antifreeze, Super-A Green, SK chemicals, Korea).

*To whom correspondence should be addressed.
Tel: +82-54-530-1215; Fax: +82-54-530-1218
E-mail: entopark@knu.ac.kr

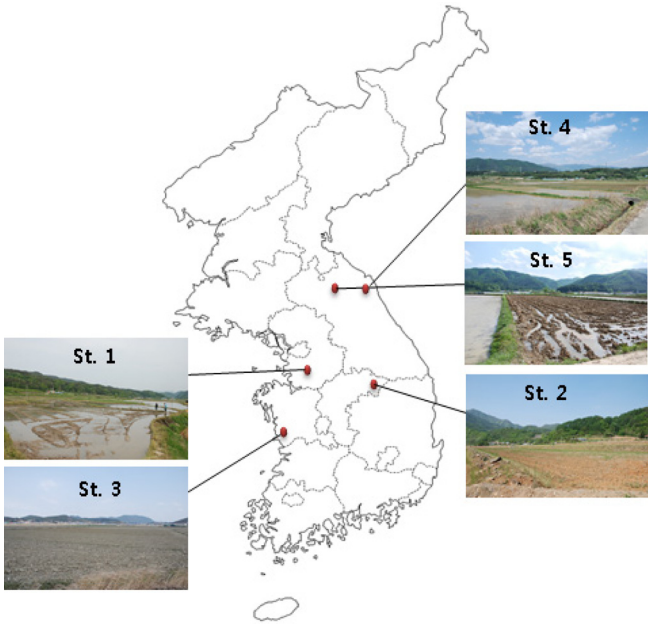


Fig. 1. The surveyed sites of ground beetles in Korea.

Pitfall traps were collected approximately every four weeks between May to July-2011.

We surveyed at the following five sites according to the administrative district in Korea (Fig. 1);

Site 1. Seongbuk-dong, Yuseong-gu, Daejeon metropolitan-city

Site 2. Daedae-ri, Gagok-myeon, Danyang-gun, Chungcheongbuk-do

Site 3. Sinsong-ri, Seocheon-eup, Seocheon-gun, Chungcheongnam-do

Site 4. Yeochan-ri, Gujeong-myeon, Gangneung-city, Gangwon-do

Site 5. Bangdong-ri, Seo-myeon, Chuncheon-city, Gangwon-do

Identification

Collected ground beetles were brought to the laboratory and dried, mounted, and identified to the species level under a dissecting microscope (Olympus, SZ40, ×20). Identification was performed according to Habu (1967, 1973, 1978), Kwon and Lee (1984), and Park and Paik (2001), Löbl and Smetana (2003), and Park (2004). The specimens examined were deposited in the J.Y. Park Collection (JYPC).

Community structure analysis

Pielou's species diversity index (H', Pielou, 1969), McNaughton's dominance index (DI, McNaughton, 1967), Margalef's species richness index (RI, Margalef, 1958), Pielou's species evenness index (EI, Pielou, 1975) and Jaccard's similarity index (Jaccard, 1908) were calculated and the formulas are as follows:

$$H' \text{ (Species diversity index)} = -\sum\left[\frac{n_i}{N}\cdot \log_2\frac{n_i}{N}\right]$$

n_i means number of individuals at i-th species and N means total number of individuals (Pielou, 1969).

$$DI \text{ (Dominance index)} = \frac{n_1 + n_2}{N}$$

n_1 means number of dominant species individuals, n_2 means number of subdominant species individuals, N means total number of individuals (McNaughton, 1967).

$$RI \text{ (Species richness index)} = \frac{S - 1}{\ln(N)}$$

S means total number of species and N means total number of individuals (Margalef, 1958).

$$EI \text{ (Evenness index)} = \frac{H'}{\log_2 S}$$

H' means species diversity index and S means total number of species (Pielou, 1975).

Results

A total of 29 species belonging to ten subfamilies were identified from 277 collected ground beetles in paddy fields (Table 1). Nine species of Harpalinae recorded the highest number of subfamily species, followed by 8 Pterostichinae, 4 Callistinae, 2 Nebriinae and 1 other subfamily, respectively. The subfamily Harpalinae had the most number of individuals (24.5%), followed by 63 Callistinae (22.7%), 59 Zabrinae (21.3%), 48 Brachininae (17.3%), 19 Pterostichinae (6.9%), 8 Licininae (2.9%), Nebriinae (2.5%), 3 Patrobinae (1.1%) and 1 other subfamily (0.4%), respectively (Fig. 2, 3).

At the genus level, 5 species of *Harpalus,* 4 species of *Chlaenius*, 2 species of *Anisodactylus*, *Nebria, Colpodes* and *Pterostichus* genus were collected. Also, the other 11 genera were for 1 species, respectively (Fig. 4). At the genus level, 63 individuals of *Chlaenius* and 59 individuals of *Amara* genus were collected, followed by *Pheropsophus* and *Harpalus* with 48 and 43, respectively (Fig. 5). The number of ground beetles species in each surveyed site were from 6 (Site 1, 3 Yuseong-gu, Daejeon metropolitan-city, Seocheon-gun, Chungcheongnam-do) to 12 (Site 2 Danyang-gun, Chungcheongbuk-do, Fig. 6). The dominant species was *Amara congrua* (59 individuals, 21.3%) and the subdominant species was *Chlaenius pallipes* (49 individuals, 17.7%). The Dominance index (DI) for each sites were 0.45 to 0.88, and the average dominance index was in the order of St. 3> St. 5> St. 1> St. 4> St. 2, respectively.

The species diversity index (H') for each sites were 1.26

Table 1. List of ground beetles collected in Paddy fields. Wing form: B, brachypterous; M, macropterous

Subfamily	Species	Wing form	St.1	St.2	St.3	St.4	St.5
Harpalinae	*Harpalus chalcentus*	M		14			4
	Harpalus tridens	M		3			
	Harpalus jureceki	M					3
	Harpalus bungii	B	5	1			
	Harpalus crates	M		13			
	Oxycentrus argutoroides	M				3	
	Anoplogenius cyanescens	M			7		
	Anisodactylus signatus	M		2	2		
	Anisodactylus punctatipennis	M	4	7			
Patrobinae	*Patrobus flavipes*	M			3		
Callistinae	*Chlaenius ocreatus*	M				1	
	Chlaenius naeviger	M				4	8
	Chlaenius circumductus	M					1
	Chlaenius pallipes	M	2	2		2	43
Lebiinae	*Calleida onoha*	M			1		
Pterostichinae	*Poecilus nitidicollis*			3			
	Pterostichus subovatus	M			1		
	Pterostichus microcephalus						4
	Dolichus halensis halensis	B				1	
	Synuchus congruus	M				2	
	Colpodes xestus	B		3			
	Colpodes japonicus						4
	Curtonotus giganteus		1				
Zabrinae	*Amara congrua*	M	8	1	44		6
Nebriinae	*Nebria chinensis*	M	2				
Nebriinae	*Nebria coreica*	M					5
Carabinae	*Calosoma chinense*	B		1			
Brachininae	*Pheropsophus jessoensis*	B		15		6	27
Licininae	*Lachnocrepis japonica*	M				8	

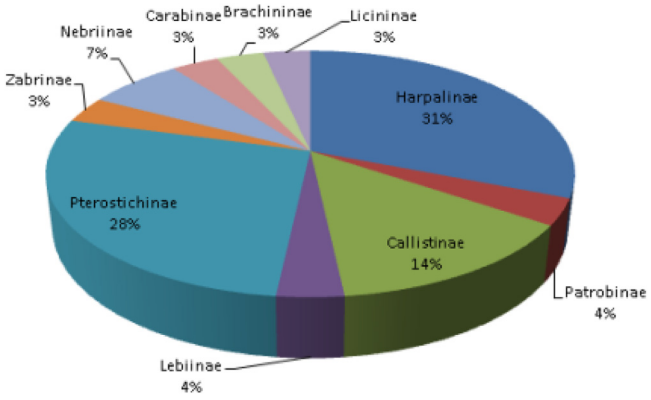


Fig. 2. Species ratio of each taxon.

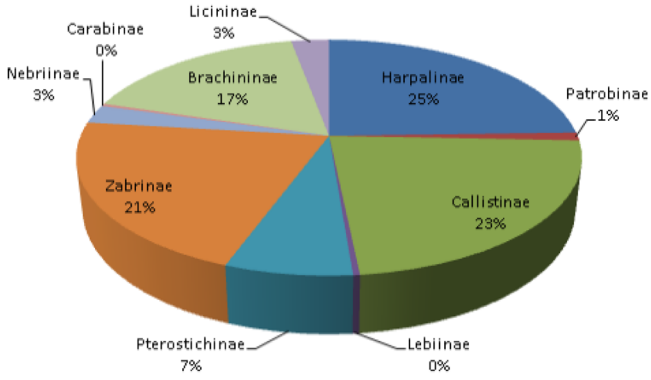


Fig. 3. Individual ratio of each taxon.

to 2.98, and the average species diversity index was in the order of St. 2> St. 4> St. 5> St. 1> St. 3, respectively.

The species richness index (R') for each sites were 1.23 to 2.64, and the average species diversity index was in the order of St. 2> St. 4> St. 5> St. 1> St. 3, respectively.

The species evenness index (E') for each sites were 0.49 to 0.89, and the average species diversity index was in the order of St. 4> St. 1> St. 2> St. 5> St. 3, respectively (Table 2).

Between Site 4 (Chuncheon-city, Gangwon-do) and Site

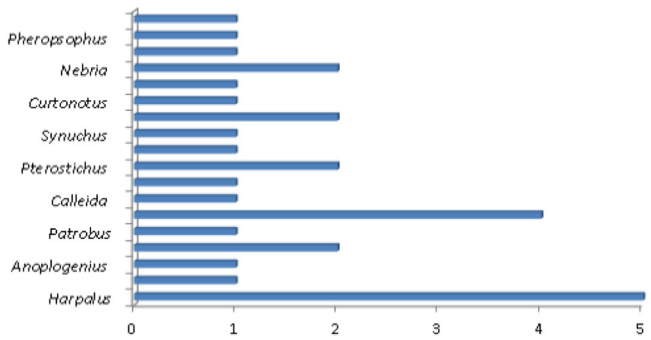


Fig. 4. The number of species of each genus.

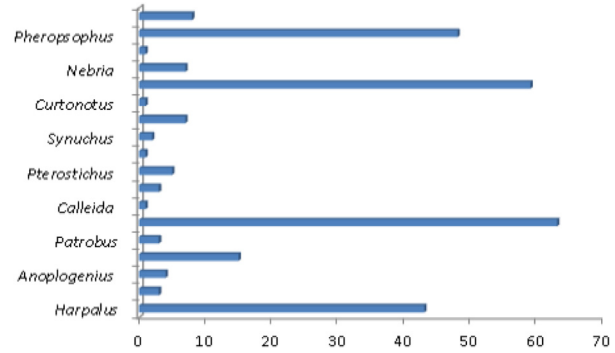


Fig. 5. The number of individuals of each genus.

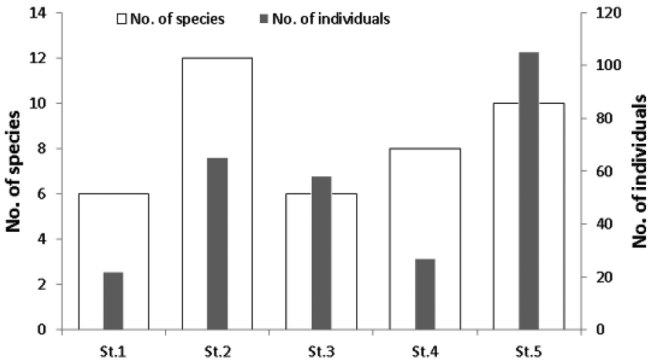
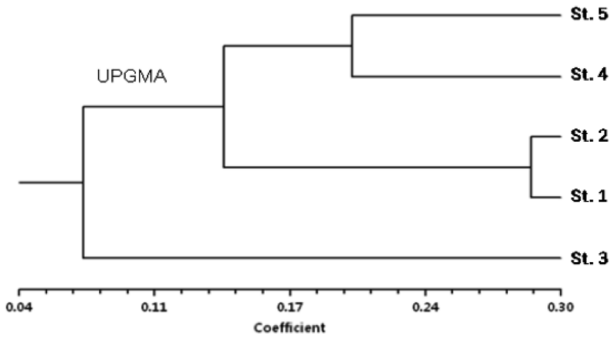


Fig. 6. The number of species and individuals in each surveyed site.

Table 2. Various community analysis of each surveyed site

Site	Num. Sp./Indivi.	DI	H'	R'	E'
St. 1	6/22	0.59	2.29	1.62	0.89
St. 2	12/65	0.45	2.98	2.64	0.83
St. 3	6/58	0.89	1.26	1.23	0.49
St. 4	8/27	0.52	2.67	2.12	0.89
St. 5	10/105	0.67	2.51	1.93	0.76
Mean	29/277	0.62	2.34	1.91	0.77

Sp: Number of species; Indivi: Number of individuals; DI: Dominance index; H': Species diversity; R': Species richness index; E': Evenness index



	St. 1	St. 2	St. 3	St. 4	St. 5
St. 1	1.000				
St. 2	0.222	1.000			
St. 3	0.200	0.111	1.000		
St. 4	0.067	0.125	0.000	1.000	
St. 5	0.143	0.286	0.077	0.091	1.000

Fig. 7. The cluster analysis of collected ground beetles in each surveyed site.

5 (Gangneung-city, Chuncheon-city, Gangwon-do) and between Site 1 (Yuseong-gu, Daejeon metropolitan-city) and Site 2 (Danyang-gun, Chungcheongbuk-do) had the similarity in the result of cluster analysis using the surveyed ground beetles (Fig. 7).

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